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Production Optimization of Associated Gas Systems: A Case Study of B Field of the Niger Delta

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Abstract— *Production optimization is a system that is usually applied for the determination and implementation of the optimum values of operating parameters in a production system so as to maximize production rate and minimize operating costs under various technical and economic constraints. Hydrocarbon production systems which involve movement or transport of reservoir fluid from reservoir to surface require energy to overcome the frictional losses or the pressure drop in order to obtain the desired optimum production rates, which is the case for both oil and gas wells. A good number of well completion factors contribute to the determination and attainment of this optimum production rate, key among these factors is the rational selection and determination of tubing sizes. At the flowing production stage, the rational tubing size can be determined by analyzing the sensitivities of various tubing sizes on the optimum rate, this can be done using the so-called nodal analysis method. The present study focused on optimizing an associated gas production system in the Niger Delta field B using production tubing sizing as a criteria. We used field data from the Niger-Delta field B and the PROSPER dynamic simulator in order to ascertain the optimum tubing size and future production performance of the associated gas system in this field. The selection of the optimum tubing size indicated the highest flow rate at minimum cost. Results provide the best production practices, showing how tubing sizes would have a significant influence on associated gas and oil production rate by 59% and 61% increments, respectively. Specifically, a 5.5 inch tube size gave the highest value of associated gas and oil production rate at 15.229MMScf/day and 12,329STB/day, respectively. The increment in tubing size enhances both operational efficiency and profitability of the field.*

Keywords— *Associated Gas Production System, Production Optimization, PROSPER software, Niger Delta Oilfield.*

I. INTRODUCTION

Oil and gas production operations as happens in the oil and gas industry can involve the production of associated gas. Associated gas is natural gas produced in conjunction with crude oil, and this natural gas exists in the reservoir either as free gas or as dissolved gas. The dissolved gas which usually occurs in the so-called bubble point reservoir can free itself from the crude during production and subsequent pressure depletion.

An increased tubing performance and the production capacity of an associated gas well can be achieved by investigating the effects of tubing sizes on production rate. Any associated gas well may need the installation of an optimum tubing size [Wan Renpu, 2011; Tan Liu et al., 2021]. Oversized tubing may cause an excessive liquid phase loss due to slippage effect or an extreme downhole liquid loading during lifting. Conversely, an undersized tubing in the production system will limit the production rate due to the increased friction resistance caused by high flow velocity.

In this work, we present a nodal analysis approach towards the optimization of an associated gas production using tubing size sensitivity approach. We select a case study of the B field in Nigeria's Niger Delta and then build a model of this configuration in the integrated software PROSPER. The model was, thereafter, used to predict the pressure at the bottom hole as well as the associated gas production rate of field B's associated gas production system, thereby maximizing recovery during the rapid depletion of the reservoir, and meeting both present and future development of the field.

II. METHODOLOGY

A. Nodal Analysis

Nodal analysis is the systems approach for the production optimization of oil and gas wells by assessing the production of the system from the reservoir to the wellhead [Brown and Lea, 1985]. The wellbore flowing pressure and the production rate are the design variables used to develop a production model that analyses and also forecasts future flow performance of the well. The so-called inflow performance relationship (IPR) model can be used to optimize completion parameters and tubing size using the nodal analysis method. Figure 1 shows the oil and gas flow from reservoir to a surface

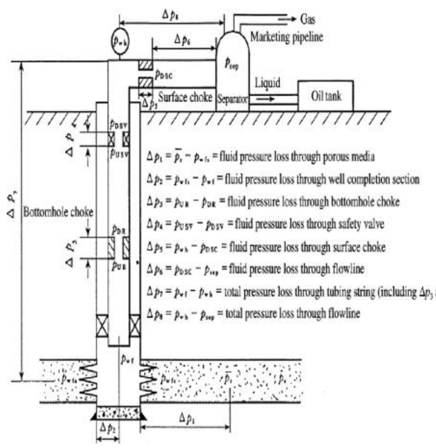

Fig. 1. Various pressure losses in the production system (Wan Renpu, 2011).

Separator. The total fluid pressure loss from reservoir to surface separator is organized in sections, including sections of pressure loss through porous media (first pressure subsystem); pressure loss through well completion (second pressure subsystem); total pressure loss through tubing string (third pressure subsystem);

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and total pressure loss through flowline (fourth pressure subsystem).

The production system of an oil and gas well can be simplified into inflow and outflow parts through selection of the solution node. For instance, when the solution node is selected at the bottomhole pressure of the oil/gas well, the inflow part will include the two subsystems, that is, the fluid flow through porous media and the fluid flow through completion section, while the outflow part includes the other two subsystems: the fluid flow through tubing string and the fluid flow through surface flowline. This condition enables the solution of the following two major optimization problems.

(i) When the parameters of the outflow part are kept constant, the completion section can be optimized using the nodal systems analysis method.

(ii) However, under the conditions of constant completion mode and parameter values, the tubing size and choke can be optimized.

Nodal analysis of an oil and gas well can also be used for solving other production optimization problems, some of which include; ascertaining the dynamic performance of a well under current production conditions, optimizing the production restriction factors and presenting adaptable stimulation and adjustment measures of an oil and gas well [Wan Renpu, 2011].

B. Modelling in PROSPER

PROSPER is a well performance, design and optimization program which is part of the Integrated Production Modeling Toolkit (IPM) [Ben Mahmud and Aman, 2017]. It is designed to allow the building of reliable and consistent well models, with the ability to address each aspect of wellbore modeling: PVT (fluid characterization), Vertical Lift Performance (VLP) correlations and Inflow Performance Relationship (IPR) model. PROSPER provides unique matching features, which tune PVT, multiphase flow correlations and IPR and match measured field data, allowing a consistent well model to be built prior to use in predictive simulations [Ben Mahmud and Aman, 2017].

C. Reservoir Description

The Niger Delta oil/gas fields are located in Nigeria-West Africa, developed from tertiary age covering an area of 7.5 hectares in the Gulf of Guinea (Burke, 1996). The thick wedge sediment mostly filled with Akata, Agbada Facies (petroleum-bearing sands) and basement found on the litho-stratigraphy (Short and Stauble, 1967). The Akata formation is the over-pressured sequence of marine shale (Doust and Omatsola, 1990). It is the source rock with the thickness between: 1,969-19,685 ft and mainly filled with the continental slope channel-filled sands and turbid clastics.

Agbada Formation is the overlying paralic sequence of several offlap cycles of unconsolidated hydrocarbon-bearing sands and the shale (cap-rock). It is predominantly filled with inter-bedded sands and shale with a thickness between 984 - 14,764 ft. It is sealed with clay smears along faults, an interbedded sealing unit and vertical seals (Doust and Omatsola, 1990). Growth fault has an impact on lateral variation thickness, reservoir geometry and quality (Weber and Daukoru, 1975). Bara basin is located in the upper Miocene formation filled with prograding clastic shoreline southwards. The geological structure has fault dependent anticline with a strong stratigraphic layer as shown in Figure 2.

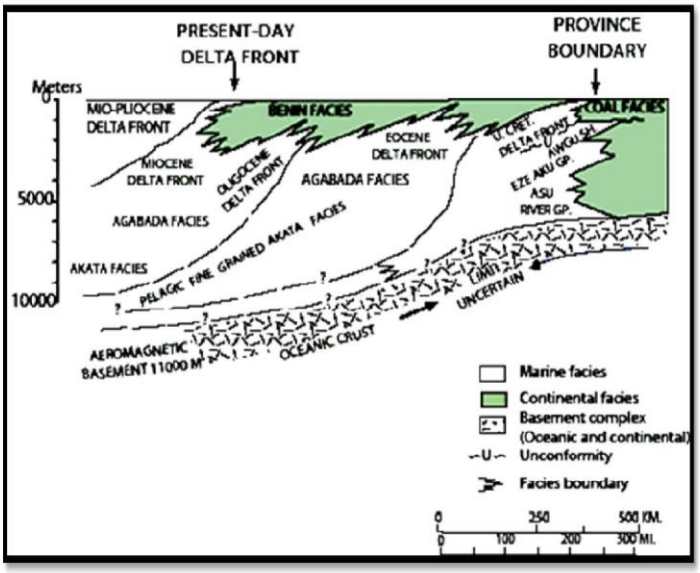

Fig. 2. Schematic geological structure of a Niger Delta Basin (Adegoke et al., 2017).

D. Well Modelling

The well model was designed and modeled using the PROSPER software. The built model predicted the flowing bottom pressure and fluid rate using data from the selected field. This involved specification of well configuration, fluid PVT characteristics, multiphase VLP correlation, and IPR model. The field data (presented in TABLE I) shows actual values of reservoir rock and fluid data used to model the well. Firstly, the PVT data, downhole equipment and IPR were modeled and then nodal analysis was carried out on nodes of interest.

TABLE I: Field Data from the Niger Delta field B

S. No.	Parameter	Value
1	Reservoir Pressure Pr:	6200 Psi
2	Depth in the middle of reservoir:	12122.7ft
3	Gas Liquid ratio:	1235.208MMScf/STB
4	Oil Saturation Pb:	6162.65 Psi
5	Relative density of oil Yo:	0.8331
6	Relative density of gas Yg:	0.7851
7	Water cut fw:	0
8	Pressure at wellhead :	290.015 Psi
9	Wellhead Temperature:	86^0F
10	Wellbore Temperature:	145^0F
11	Tubing size, OD	3.5 in

The PROSPER model was used to determine sensitivity on the following tubing sizes:

i. 2 inches
ii. 3.5 inches
iii. 4 inches
iv. 5 inches
v. 5.5 inches.

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III. Results And Discussions

A. PVT Data Analysis

PVT data was used to predict gas evolution (from oil phase) as the fluid flows to surface conditions which enabled us to obtain the bubble point, critical point and dew point. The PVT data and fluid composition analysis was done using the Beal et al correlation.

B. Generating the IPR Curve

The IPR curve was generated using data in TABLE I and the Vogel IPR model. We base the IPR calculation on a single flowing bottomhole pressure and surface test rate. Figure 3 shows the IPR curve which produce a formation productivity index of 3.52 (STB/day/psi) and an absolute open flow (AOF) of 15002.9(STB/day). This indicates the maximum achievable flow rate, if there is no pressure drop between production tubing components.

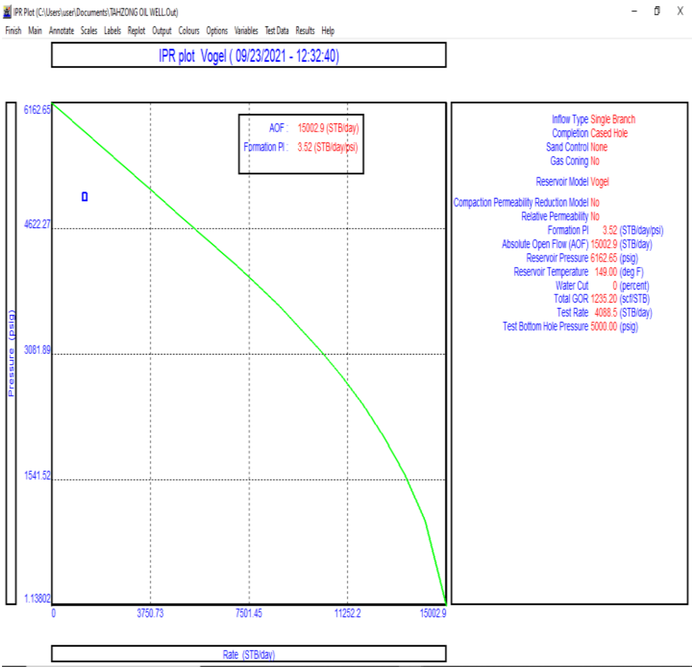

Fig. 3. IPR curve for associated gas reservoir.

As production proceeds, the reservoir pressure will be depleted significantly. This reservoir pressure depletion has a tangible effect on IPR curves variation and will cause a significant reduction in the IPR curve magnitude and AOF values.

It is seen in Figure 4, that as the reservoir pressure declines from 6162.65 psi to 1000 psi, the Absolute Open Flow potential decreases from 15002.9-1969.11 STB/day, suggesting a high sensitivity of the model (see IPR curve) to changes in reservoir pressure.

C. Estimation of Wellbore Flowing Pressure and Production Rate

Production data from the Niger Delta Field B indicates that the well is expected to commence production in 2027. At first, a reservoir drive mechanism will support the early production stage involving VLP and IPR curves. The operating point as determined from the IPR and VLP curves enabled the estimation of import wellbore flowing pressure and fluid rates: 3167.55psi, 9949.4 STB/day and 12.286 MMSCF/day. This model was then used for further analysis.

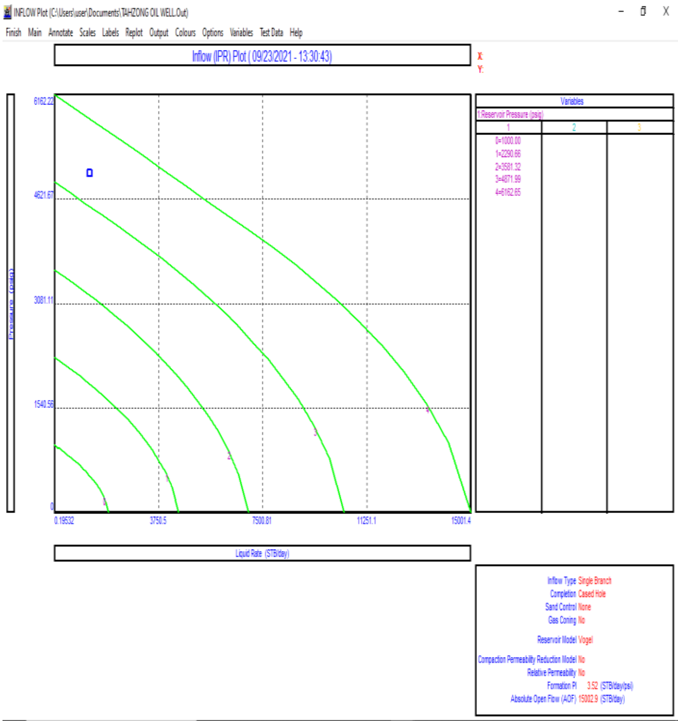

Fig. 4. Effect of reservoir pressure depletion on the IPR curve.

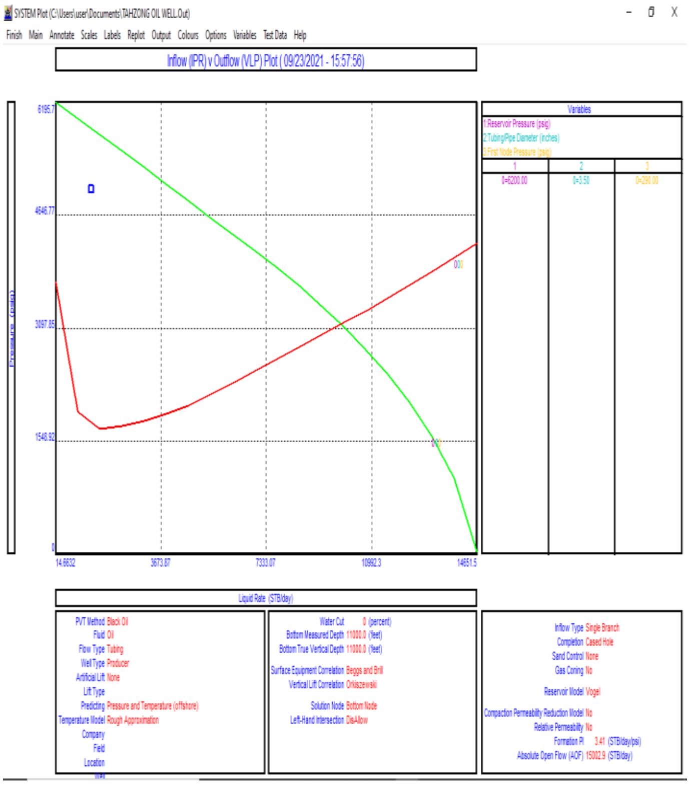

Fig. 5. System plot towards determining the operating point.

D. Tubing Size Sensitivity Analysis

In the sensitivity analysis on tubing size towards an optimization process, we monitored the change on the well in the field and knew how possible it is to increase production. It was found that applying this optimization strategy on all the wells yields more associated gas production for the various tubing sizes, ranging between 2.875-5.5 inches that were considered for this case study well of the Niger Delta field B.

Each tubing size was specified and results analyzed to determine the optimum operating conditions as shown in Fig. 6. Table II tabulates the production rates observed for various tubing sizes. Observe both the crude oil and associated gas gains from the optimization process. The results show that the 5.5inch sized tubing gave the highest associated gas and oil production rate at 15.229MMScf/d and 12,329STB/d respectively, from the initial 2.875 inch specification.

Therefore, the 5.5in tubing size promotes the highest optimum rate compared to the other tubing sizes: 2.875, 3.5, 4.0, 4.5 and 5.0 inches. Also noting the fact that large tubing size should be used in a high productivity well, considering the high productivity index of the reservoir at 3.5 STB/day/psi, the 5.5in size is the best option, and hence the optimum tubing size, given its relatively high production rate.

TABLE II. Results of Tubing Size Sensitivity Analysis.

S. No.	Tubing size (inches)	Oil rate (STB/day)	Gas rate(MMSCF/day)
1	2.875	7679.4	9.597
2	3.5	9938.8	12.276
3	4	11081.2	13.688
4	4.5	11810.1	14.588
5	5	12190.3	15.058
6	5.5	12329.0	15.229

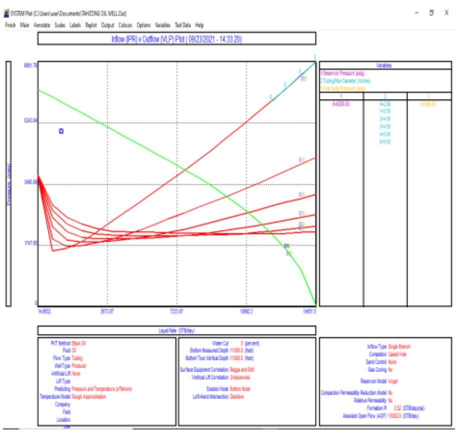

Fig. 6. Effect of tubing size on the optimum rate.

IV. Conclusion

Dynamic nodal system analysis was utilized in ascertaining the optimum present and future production performance of an associated gas system in the Niger Delta field B. Findings suggest that tubing size 5.5in gave the highest value of associated gas and oil production rate at 15.229MMScf/d and 12,329STB/d respectively. This was modeled on Prosper using data from the identified field. Expectedly, the tubing size optimization processes resulted in increasing associated gas and oil production by a significant percentage, ensuring lower energy consumption, higher flowing time, operational efficiency, and profitability, respectively.

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